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**Measuring the Impact of Light Rail Systems
on Single Family Home Values:
A Hedonic Approach with GIS Application**

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ABSTRACT

In theory, proximity to a light rail (LRT) may have two different effects on residential property values. On the one hand, accessibility (proximity to the LRT stations) may increase property values. On the other hand, nuisance effects (proximity to the LRT line and stations) may decrease property values. Existing empirical studies are inconclusive, and failure to separate the effects of accessibility from the nuisance effects may explain some of the ambiguity. This paper examines the impact of the light-rail system (MAX) in Portland, Oregon, on single-family home values using distance to rail stations as a proxy for accessibility and distance to the line itself as a proxy for nuisance effects. Geographic Information System (GIS) techniques are employed to create spatial-related variables and merge data from various sources. The study results confirm our hypothesis that the light rail has both a positive effect (accessibility effect) and a negative effect (nuisance effect) on single-family home values. The positive effect dominates the negative effect, which implies a declining price gradient as one moves away from LRT stations for several hundred meters. Without controlling for the nuisance effect of the distance to the rail line, the estimated coefficients on distance from stations appear to be biased and would underestimate the accessibility effect. The finding of an independent nuisance effect suggests that previous hedonic models may have reached contradictory results because the nuisance effect differs with different types of rail or other local characteristics.

Key Words: Light rail, impact, housing, accessibility, nuisance, GIS

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Economic theory predicts that access to transportation services should be capitalized into property values. The capitalized value provides some measure of the value of such access. Yet access itself is difficult to measure, and distance is typically used as a proxy for various types of access. However, distance can be a proxy for a number of other effects as well. This study attempts to refine the use of distance from light rail stations as a measure of the value of access by also controlling for distance from the rail line itself.

The current study, to a certain extent, is a replication and extension of Al-Mosaind et al. (1993), which examined the impact of proximity to Portland's light-rail stations on residential property values. One motivation for the current study is that past studies suggest that housing markets may take time to reach an equilibrium (Nelson 1990, Gatzlaff et al. 1993) and the previous study is based on 1988 data, only two years after the opening of light rail. Our current study uses 1992 to 1994 data, which is six years after the light-rail operation and uses a much larger data set. Another, and more important, motivation is that existing station impact studies, including Al-Mosaind et al.'s 1993 study may be subject to omitted-variable bias. Previous studies use distance to the station as a proxy for access, but stations and rail lines also have negative attributes associated with noise and other nuisances. These negative effects should also decline with distance. This study includes both distance to station and distance to the rail line in the model,

which allows us to partially separate the accessibility effect and the nuisance effect. In addition, Geographic Information System (GIS) techniques are employed and shown to be a useful tool in doing spatial-related studies.

2. Theoretical Background and Literature Review

The hedonic price method relates the price of a property to a bundle of attributes or characteristics that theoretically affect its value. Holding other variables constant, the change in the price of a house that results from a change in any particular attribute is called the hedonic price or implicit price of an attribute. In a well-functioning market, utility-maximizing households will purchase houses so that their willingness-to-pay for a marginal increase in a particular attribute equals its hedonic price. Consequently, in equilibrium, the hedonic price of an attribute can be interpreted as the willingness-to-pay for a marginal increase in that attribute.

In theory, the hedonic-price method can be used to value incremental changes in the level of many goods that are not traded in markets, such as externalities and public goods. In practice, there are several potential problems. First, people must know and understand the full implications of the characteristic being examined. Second, it is important that the hedonic price equation include as explanatory variables the attributes that households really do value, not more readily obtainable but incorrect proxies. Third, there should be enough options available that families can find an optimal package, that is, a house with just the right combination of attributes. In other words, there should be sufficient variety so that families can vary one characteristic while holding others constant. Fourth, market prices should be in equilibrium with respect to the attributes of interest and other factors that affect demand or supply. Fifth, there may be multicollinearity problems in the data. For example, if expensive houses were large and located mainly in polluted areas, it would be difficult to estimate separate hedonic prices for pollution and size (Boardman 1996).

Based on the existing literature, e.g., Miller (1982), Freeman (1979) and Ridker et al. (1967), there are four categories of housing attributes that are important in influencing housing prices:

- (1) Physical attributes of the house itself, including housing quality and quantity: frequently included variables are lot size, house size, number of bedrooms, number of bathrooms, presence of basement or not, age of building.
- (2) Neighborhood attributes, such as median household income, occupation structure, white / minority ratio, school quality, crime rate.
- (3) Locational attributes: distance to CBD and other major business or employment centers are included as proxies for locational attributes to measure accessibility.
- (4) Fiscal and economic externalities: property tax, public facilities, zoning, air quality, proximity to a power plant, shoreline, traffic externalities.

Public facility effects on property values have received more than their share of research attention. Lyon (1972) theorizes that there are two components of the impact a facility might have on housing sale prices -- one is the accessibility effect (positive effect), the second impact would be

the more intangible visual effect or noise effect of the closeness to the facility. Most studies use a distance measure from the facility, often with nonlinear effects hypothesized and often found. There is a hypothetical maximum value effect some distance away from the facility (Miller 1982).

The current study, the impact of LRT station access on housing values, fits well into the above framework. On the one hand, proximity to LRT stations may improve the accessibility of residents and may reduce commuting costs. These may be positively capitalized into home values. On the other hand, living close to the LRT station and line may increase noise, traffic, pollution, and other nuisances, with a resulting decline in home values.

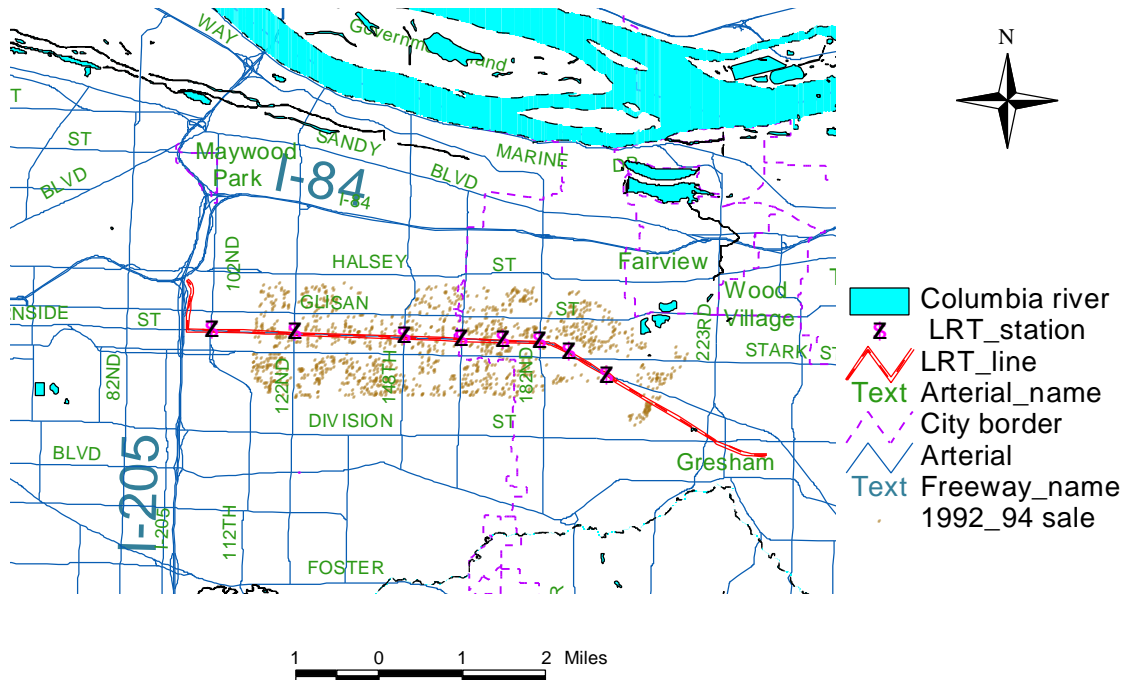
The evidence of the existing literature on the impact of light rail or heavy rail on property values is mixed. Damm et al. (1980) found a significant positive impact of the new Washington metro system on property values. Lee et al. (1978), Bajic (1983), Voith (1991), and Al-Mosaind et al. (1993) also had similar findings. On the other hand, Forrest et al. (1996) study the impact of light rail in Greater Manchester, Britain, and find that proximity to light-rail stations tends to lower property price. The Nelson et al. (1990) study of Atlanta, Georgia and the Gatzlaff et al. (1993) study of Miami, Florida find inconclusive results regarding the overall impact of the rail systems.

3. Study Area and Data Preparation

Al-Mosaind et al. (1993) study the area along the eastside Burnside corridor of the light-rail system (MAX) in Portland, Oregon, extending from Interstate 205 (west) to N.E. 192nd Street (east), between N.E. Glisan (north) and S.E. Stark Street (south). The current study area is modified in several respects. Figure 1 shows the current study area. The westside boundary is reduced to the area between 102nd Ave. and 122nd Ave., excluding one LRT station that is next to I-205 in order to eliminate the impact of access to the Interstate. The eastside is expanded into the area between 182nd Ave. and 223rd

Ave. in order to achieve a relative balance of observations between the cities of Portland and Gresham. The north and the south boundaries are expanded up to about 1000 meters from the LRT line because a recent study suggests that people are willing to walk a longer distance to LRT stops than to bus stops, and using bus walking standards (400 to 500 meters) would result in an underestimate of LRT attraction. The 75th-percentile walking distance to LRT stops is about 840 meters. Combined with an average circuitry of 1.24 (calculated as the actual walking distance divided by the straight-line distance between the house and its closest LRT station), the recommended design guideline for the catchment area is 700 meters from local and transfer stations (O'Sullivan et al. 1995). The study area is dominated by developments of single-family homes.

FIGURE 1: The Study Area and Its Vicinity



Sale prices of single-family homes sold from 1992 to 1994 are used for this study. Data are retrieved from two regional data bases: the Regional Land Information System (Metro, 1995) and MetroScan from Transamerica Intellitech, inc. In addition, the 1990 Census is used to provide neighborhood information for each census block group. Merging data is done based on the common unique identifiers in RLIS Lite, MetroScan and the Census data base. GIS is also employed to calculate four spatial-related variables: distance to the nearest LRT stations, shortest distance to the LRT line, distance to the nearest park, and distance to the CBD (Portland City Hall) from each house. These are the focus variables in this study. For more information on the use of GIS in this context, readers can refer to the paper by Rosiers et al. (1992).

Three types of cases are deleted from the data set: (1) Cases with missing information for some of the variables. (2) Cases with sale dates before built dates, indicating that the sale was not for the finished home. (3) Cases with sale prices less than 50% of assessed values since such sales probably do not reflect market transactions. After deleting these cases, 830 observations remain. The distribution of observations is relatively homogeneous across our study area.

After preliminary regressions were run, residual analysis was employed to help identify outliers with regression residuals larger than 3 standard deviations. Nine such outliers were identified and these nine outliers were then checked individually. It was decided to exclude them from further regression analysis since the reported sales price seemed likely to be a misrepresentation. For

example, seven out of the nine have either a very large or small ratio of sale price vs. assessed value (smaller than 60% or higher than 130% of assessed values).

4. Functional Forms and Model Specification

It has been argued that the functional form of the model is as important as the quality of the data and selection of the variables (Miller 1982). There is a general consensus in the hedonic housing literature that the choice of the functional form cannot be determined a priori given the lack of a theoretical basis. There have been two basic approaches. First, studies on the estimation of demand for housing characteristics have generally chosen a non-linear form which is estimated using the Box-Cox transformation procedure. The second approach has used either a linear semi-log, or double log functional form (Can 1992).

This paper takes the second approach and estimates two functional forms: A semi-log and a double log one. In the semi-log form the estimated attribute coefficients indicate the percentage change in housing price with a unit change in any of the attributes whereas for the double log form, the estimated attribute coefficients represent a percentage change in housing price associated with a percentage change in any of the attributes (elasticity). Both semi-log and double-log models are run for the whole data set and the subset within 700 meters of an LRT station. When all observations are used, a dummy variable separates those observations beyond 700 meters of an LRT station. For the regressions using only observations within 700 meters of a LRT station, two variables are employed to separate the accessibility effect and the nuisance effect, the straight-line distance between each house and its closest LRT station and the shortest distance between each house and the LRT line.

The general price equation is as follows:

$$P = a + b X + r Z + e$$

Where: P is the sales price or log transformation;

a is constant term;

X is a vector of control variables;

Z is a vector of spatial-related variables;

e is the random error term;

and a , b , r are parameters to be estimated.

The dependent variable is sale price or its log transformation; the independent variables include age of building structure and its square term, lot size and its square term, house size and its square term, number of bedrooms, number of bathrooms, number of fireplaces, average household size for the block group, median house value in the block group, median income in the block group, percentage of people over 65 years old in the block group, minorities as a percentage of the population in the block group, distance to CBD (using the Portland City Hall to represent the CBD) and its square term, distance to the LRT line and its square term, distance to the nearest park and its square term, distance to the nearest LRT station and its square term. The last four variables are GIS created variables, and all are straight-line distances. In addition to the above numeric variables, the following dummy variables are also included: w/ air conditioning, w/ basement, w/ attached garage, w/ swimming pool, corner location, cul-de-sac location, located in a single-family zoning area, located in Portland, sold in 1993, sold in 1994. The use of the last two variables, sold in 1993 and sold in 1994, is to capture the inflation or appreciation effect over time. Sold in 1992 is the base year.

A common problem in hedonic pricing research is multicollinearity of the variables. Pair-wise correlation coefficients and variance inflation factors (VIFs) show no serious correlation between our focus variables and the control variables. We try to control as many relevant variables as possible to avoid omitted variable bias. Multicollinearity among the included variable is a less serious problem with a large sample like this.

Our main hypothesis is that the accessibility effect, represented by distance to LRT stations and its square term, will show a decline in house value with increasing distance, other things equal. On the other hand, the nuisance effect, represented by distance to the LRT line and its square term, will show higher housing prices with distance from the line itself. The combined effect when moving away from the station and perpendicular to the line might be the hedonic price curve shown in Figure 2.

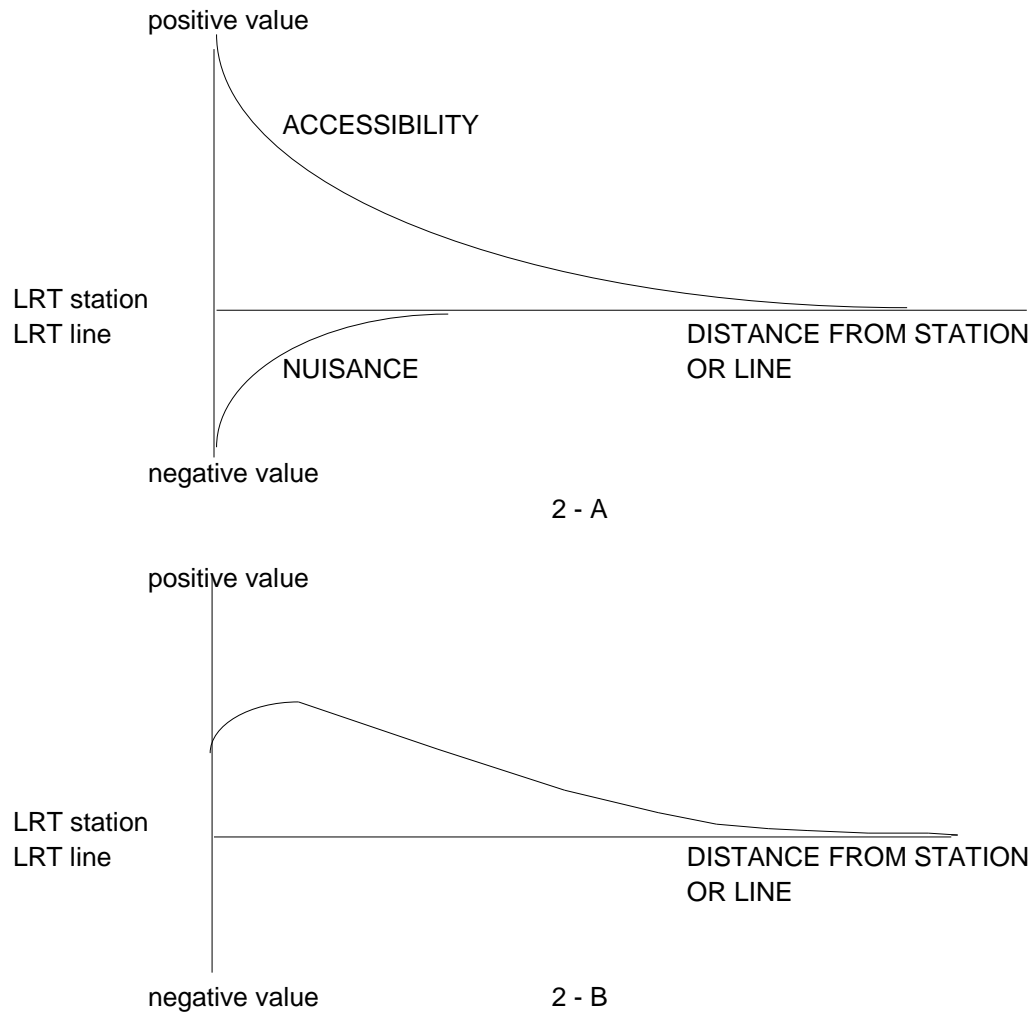


FIGURE 2 - Effects of Light Rail on Single Family Housing Values
(Adopted from Li and Brown (1980))

5. Results

Detailed regression results for the model using a dummy variable to represent the effect of proximity to the LRT station are not reported here because the coefficient for the focus variable, the dummy variable that separates the observations into within and outside 700 meters of an LRT station, is not statistically significant. Also, this value has an unexpected positive sign. This seemingly strange result may be due to possible omitted variables in the model. For example, the Columbia River lies to the north of the study area and parallels the LRT line. Also, there is a very big park in the northern part of the study area. Presumably both of these would favorably affect housing values but would also be correlated with distance from the LRT station or line. Similar examples can be found to the south of the study area. Further, the use of a dummy variable does

not allow one to estimate the rate at which property values fall as a function of distance, so the property values could be falling with distance from the LRT, but the dummy variable would not capture this effect because it, in effect, only compares the average values of the two areas. The remaining regressions used only the data for houses within the 700 meter distance to an LRT station.

TABLE 1: Results of Semi-log Regression for Less Than 700m Cases

Variable	Coefficient	T
Age of house in years	-.002048	-2.014*
Age of house squared	2.80860E-05	2.104*
Lot size in square feet	1.66096E-06	1.552
House size in squared feet	2.36795E-04	3.226**
House size squared	-4.80732E-08	-1.798
Number of bedrooms	.021725	2.672**
Number of bathrooms	.024202	2.151*
Number of fireplaces	.032279	4.204**
Corner location	.011927	.885
(1=Yes, 0=No)		
Presence of basement	.065506	2.424*
(1=Yes, 0=No)		
Presence of attached garage	.041541	3.517**
(1=Yes, 0=No)		
Median house value for census	1.31943E-06	2.047*
blockgroup in dollars		
Single family zoning	.025093	1.698
(1=Yes, 0=No)		
Distance to nearest park	-9.62990E-06	-1.735
in feet		
Distance to CBD in feet	-5.44561E-07	-.425
Distance to LRT line in feet	3.40717E-05	1.016
Distance to nearest LRT	-1.49524E-04	-2.538*
station in feet		
Distance to LRT line squared	-2.41404E-08	-1.588
Distance to nearest LRT	5.33251E-08	2.647**
station squared		
Locate in PORTLAND	-.012558	-.743

(1=Yes, 0=No)		
Built in 1993 (1=Yes, 0=No)	.033503	3.302**
Built in 1994 (1=Yes, 0=No)	.066700	6.498**
Constant	4.571014	47.333**

Total Cases = 302
R Square .625
Standard Error .069
F = 20.160**

1. 1 foot = 0.3048 meter.
 2. 1 squared foot = 0.0929 squared meter.
- * Significant at the 0.05 level (two-tailed test).
** Significant at the 0.01 level (two-tailed test).

The results of the semi-log model for the cases within 700 meters of an LRT station are shown in Table 1. Some variables that are not significant at the 0.10 level and are not of direct concern are excluded from the tables.

From the table we can see that most of the variables are significant at least at the 0.05 level. For example, the variables age and age-square are both significant at the 0.05 level. The literal interpretation of the coefficients is that a one year increase in age will result in a 0.20% decrease in price for newer homes but at a decreasing rate for older homes. The minimum price with age is reached at 36.46 years. Beyond that, the estimated housing prices go up. That is to say, prices tend to decrease with age, but much older houses may enjoy a price premium. Another possible explanation is that old houses are more likely to have been renovated. One must use care in interpreting the effect of these square terms at the extremes, and the most reasonable interpretation is that the effect of age on value reaches a minimum after 36 years. Building square footage and its square term are significant at the 0.01 and 0.08 levels respectively. Housing price goes up with increased house size but at a declining rate. Housing prices tend to go up with proximity to the parks. The distance to the CBD and location in Portland are not statistically significant. A possible explanation is that they are highly correlated with each other, and the study area is not very large, so even this large sample does not allow for estimation of statistically significant differential effects.

Of our focus variables, distance to an LRT station and its square term (the accessibility effect), are significant at or close to the 0.01 level. The literal interpretation is that the housing price decreases when its distance to the LRT station increases, but at a declining rate because the effect of the square term of distance to station increases at an accelerated rate. The minimum price is reached at 427.33 meters (1402 feet) away from stations, which implies a 10.5% price difference. After that, the estimated prices start to go back up, but within the actual distance for all houses in the sample, the net effect is still negative. For example, at 100 meters (328 feet) away from stations, each additional meter (3.28 feet) further away from the LRT station will result in a \$32.20 decrease in price for an average price house at \$85,724. Compared with the \$21.75 per

meter decrease in price found by Al-Mosaind et al., this result is reasonable, especially when we consider the impact of inflation (there was a small amount of housing price inflation in Portland during the four years between our and their data) and the nuisance effect.

The other focus variables, distance to the LRT line and its square term to proxy for the nuisance effect, both have the correct sign. Housing prices go up with distance away from the LRT line, but the effect diminishes rapidly and reaches a maximum at 215.1 meters (705.7 feet) from the LRT line. However, this estimate is not statistically significant. Nevertheless, failure to include the variable results in distortions for the distance to station variable. Regressions run without the distance-to-line variable show a smaller but still statistically significant decline in value with distance from the stations (The estimated coefficients for the variable distance to station and its square term are $-1.19251E-04$ and $3.59833E-08$, and the t-ratios are -2.196 and 2.004 respectively). This implies that there are combined effects and that previous studies may have found inconsistent results or underestimated the value of access by not separately accounting for the nuisance and accessibility impacts of rail lines and stations.

We can see that the accessibility effect dominates the nuisance effect and the nuisance effect declines much faster than the accessibility effect. This implies a hedonic price curve like that in Figure 2 - B for movement directly away from the station and line, but with only the distance from station effect as one moves away parallel to the LRT tracks.

6. Conclusion

The results of this study confirm our hypothesis that the light rail has both a positive effect (accessibility effect) and a negative effect (nuisance effect) on single-family home values. The positive effect dominates the negative effect, which implies a declining price gradient as one moves away from LRT stations for several hundred meters.

Without controlling for the nuisance effect of the distance to the rail line, the estimated coefficients on distance from stations appear to be biased and would underestimate the accessibility effect. The finding of an independent nuisance effect suggests that previous hedonic models may have reached contradictory results because the nuisance effect differs with different types of rail or other local characteristics. This finding also suggests that noise, increased pedestrian and automobile traffic, attraction of undesirable groups to neighborhoods, and division of neighborhoods by LRT lines do pose a problem. Planners and policymakers who are concerned with promoting the use of public transportation have to address this issue seriously. Nelson et al. (1990) have a detailed discussion on the ways to minimize adverse effects and maximize beneficial effects of LRT on nearby neighborhoods.

Also, this study, to a certain extent, supports O'Sullivan's (1995) survey result that people are willing to walk longer to LRT stations than to bus stops. Our estimated parameters imply that the positive impact of access to a rail station persists for over 800 meters from the station. More studies are needed on the acceptable walking distance to LRT stations.

7. Suggestions for Future Study

Since, theoretically, walking distance along a street network is more relevant in measuring the accessibility of the LRT station than is the straight-line distance, a future study should focus on the walking distance. Other possible refinements would be to more carefully model the nuisance effects of an LRT station and line. For example, the noise and congestion impact is likely to be much greater near the station than it is at other points along the LRT line. Since this can not be readily separated from accessibility, some more direct measures of the magnitude of the negative impacts would be highly desirable. This would also allow for better identification of methods to minimize this negative impact. Finally, the impact of accessibility on other types of land use, particularly apartments and condominiums should be estimated.

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